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Seasonal ices and gullies on Mars studied with CaSSIS

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Abstract

Gullies on Mars are kilometer-scale downslope mass wasting systems that resemble water-worn gullies on Earth. Recent observations have revealed that they are active today and that this activity is linked is linked with the seasonal frost cycle of carbon dioxide. In this study we use images from the Colour and Stereo Surface Imaging System (CaSSIS) aboard ESA's Trace Gas Orbiter (TGO) to study the relationship between surface frosts and gullies.

1. Introduction

Gullies on Mars were first reported in 2000 [1] and were hailed as evidence of recent liquid water flows on Mars. Since that time monitoring of gullies has revealed they are active today at times of year when the martian surface is at its coldest and when CO_2 is condensed on the surface [2,3]. To the first order the distribution of CO_2 frost [4,5] and the geographic locations of gullies [6] match - between latitudes of 30° and 45° on pole-facing steep slopes and 45° to the poles on slopes with any orientation. Detailed observations of gullies on martian sand dunes has hinted at a complex interplay between frosted and non-frosted surfaces [7] and recent gully-deposits have been observed to be emplaced atop frosted gully-fans [3]. In order to explore the relationship between surface frosts and gully-activity further we focus on Sisyphi Cavi near the south pole of Mars, where gully-activity has been studied [8] and CaSSIS obtained a dense temporal coverage of in 2018.

2. Approach

We use CaSSIS colour images in order to study the relationship between surface frosts and gullies in Sisyphi Cavi. CaSSIS has four colour filters: BLU, PAN, RED and NIR (centred on 500, 675, 836 and 937 nm respectively; see [9]); where the BLU filter is particularly useful for picking up surface frosts [10]. the timing of surface defrosting is latitude dependent. Although the images we use in this study are not from the same latitude we are able to place them into "defrosting" order by using surface temperature measurements from the Thermal Emission Spectrometer (TES) aboard Mars Global Surveyor. We assume that the surface materials vary little over this constricted region and hence thermal inertia variations are less important than latitude in controlling defrosting-timing at a regional scale.

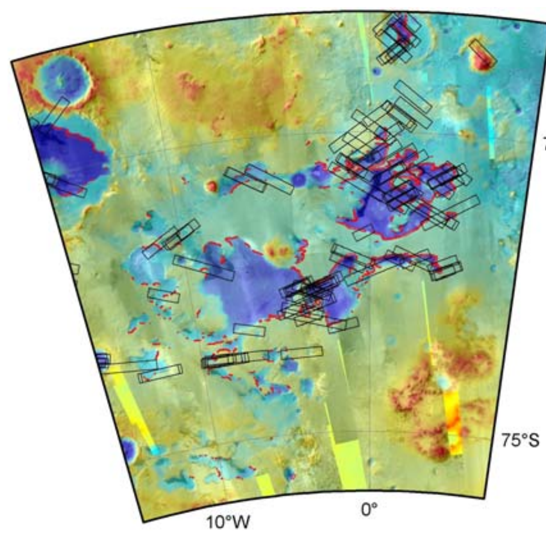

Figure 1: *Map of CaSSIS footprints over Sisyphi Cavi on a MOLA colour-coded elevation map with shading from CTX. Gullies are mapped in red and CaSSIS PAN filter footprints are in black.*

3. Results and discussion

In winter frost covers all surfaces and dark spots and fans can be seen across the slopes with gullies and preferentially around the gully channels (Figure 2a). The dark spots seem to form preferentially on sandy surfaces; such as the dunes at the bottom of Figure 2a. This is consistent with previous observations and has been interpreted to be the surface expression of gas-jets generated by the sublimation of CO_2 underneath a continuous slab of CO_2 ice on the surface [11]. The jets occur when the pressure fractures the slab ice. As the surface temperature increases towards 200K the top of the slopes are the first to defrost (Figure 2b) followed by sun facing parts of the alcoves and channels (Figure 2c). Notice in both Figures 2b and 2c that the base of the alcove remains frost covered. As the surface temperature approaches and exceeds 250K and the surrounding terrain is completely defrosted, the last parts of the gully to remain frost covered are the fans (Figure 2d). We interpret this to be a result of the fans having slightly lower thermal inertia than the surrounding materials. This lower thermal inertia could be because the fans have a lower content of water ice (i.e. a thicker lag on top of the ice-table), because of recent depositional events. It is at this time of year when gullies are active [8]. Hence we infer that for gully activity to occur there needs to be both frosted and defrosted surfaces available to drive vigorous sublimation of the CO_2 ice [3,7]. Finally, once defrosting has almost fully completed and surface temperatures have reached their seasonal maximum of ~270K the only remaining surface frosts are in pole-facing niches at the base of gully-alcoves (Figure 2e).

4. Conclusions

- Ices and patterns of defrosting are easy to monitor with CaSSIS.
- Gully-alcoves defrost before the fans and gullies defrost later than surrounding terrain – suggests activity is driven by the availability of "hot" sediment to trigger more efficient sublimation.
- Further work will examine whether frost patterns differ where activity occurs.

Acknowledgments

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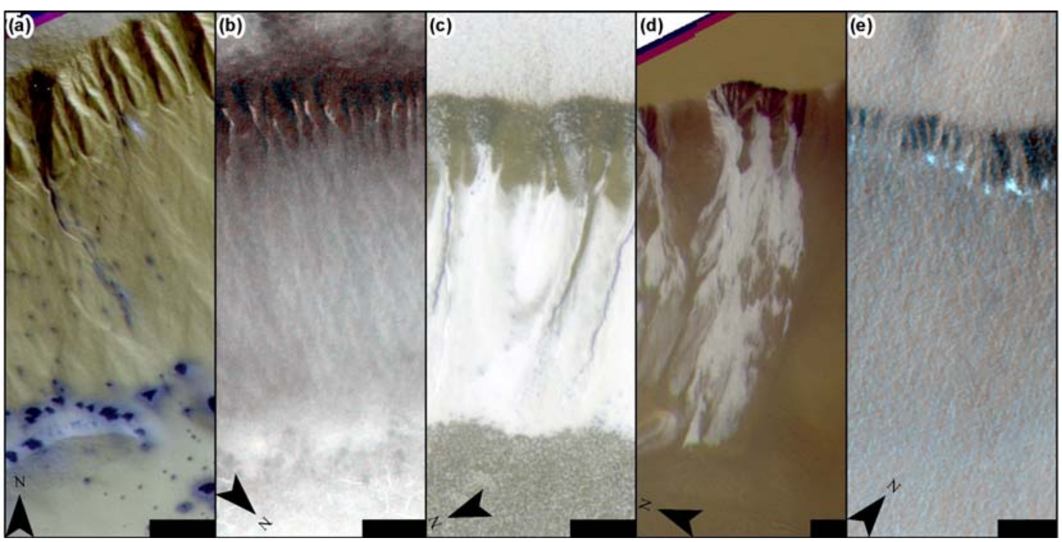

Figure 2: *Defrosting of gullies in Sisyphi Cavi as seen by CaSSIS. (a) MY34_002397_317_1, Ls 189° at 07:55 and 73°S. (b) MY34_003751_266_0, Ls 257° at 03:23 and 73°S. (c) MY34_003454_281_0 Ls 241° at 12:38 and 70°S. (d) MY34_003464_256_2, Ls 242° at 07:22and 68°S. (e) MY34_004349_276_2, Ls 288° at 18:01and 73°S.*